The movement radius of *Patella* spec. around its home scar correlates with duration of water exposure

Parsi-Pour, Parima; p.parsigmx.net
Schaal Moreno, Guillem; g.schaalmoreno@yahoo.de

Abstract
With its extraordinary ability of orientation enabling home fidelity the limpet *Patella* has been of high interest for scientists during the last two centuries. To assess possible correlations between limpet behaviour and distance to the low water line it is useful to observe their active movement range from one low tide to the next low tide and also from day to night. By comparing photographs taken each day and night over the test duration we determined a degree of home fidelity of 94.2% at the rocky shores of the Breton Atlantic coast. We also observed a positive correlation between the proximity of the limpet's home scar to the low water line and its movement radius. We present an adequate strategy as uninvasive as possible for similar studies. .

Introduction

The behaviour of intertidal organisms changes in close correlation with the tides (Fingerman 1957). Members of the marine gastropod genus *Patella* inhabit rocky shores between the border of the sublittoral zone and the upper shore line where they are constantly exposed to the influences of the tides (Davis & Fleure 1903). During high tides and low tides at night they graze on the rocks feeding on algae. During the day ebb tide forces them to return to their home scars, that perfectly match their shell margins using chemical and olfactory orientation (Edelstam & Palmer 1950; Funke 1968) . Exposed to air with a high risk of predator attacks they remain at their home scars where they adhere themselves firmly to the ground using their shell muscles (Funke 1968). Since Lukis studied *Patella* for the first time in 1831 there have been many studies trying to solve the mystery of the limpet's orientation mechanisms and activity (Davis & Fleure 1903; Villee & Groody 1940; Edelstam & Palmer 1950; Kohn 1961; Funke 1968; Maier & Mielke 2016). However, little has been done to characterise correlations between the animal's movement activity and their geographical position in the tidal zone.The aim of this study is to (i) re-assess *Patella*'s site fidelity and (ii) test for correlations between individual moving ranges and home scar positions along a transect from the low to high water lines. By observing the limpets in their natural habitat we were able to deploy methods which in contrast to previous studies did not interfere with the animal's chemical orientation.

Material and Methods

Test sites and organisms

Two different areas were used for the experiments. Both selected areas were rocky intertidal zones of the Atlantic coast. The first area was in front of the Marinarium in Concarneau (France) and the second area was in Le Cabellou (France), south of the fort. Each area was subdivided in 3 zones (1,2 and 3 in Concarneau and 4,5 and 6 in Le Cabellou). The areas 1 and 4 were approximately at LWL + 177 cm , 2 and 5 approximately at LWL + 237 cm and 3 and 6 approximately at LWL +297 cm. It was made sure, that the zones were composed by coherent areas without gaps and that they were easily accessible from above to take pictures and to observe all individuals. 120 Individuals belonging to the genus *Patella* were observed, 20 in each zone. The chosen individuals were marked with nail polish on top of their shell to be distinguished from the other individuals in the nearby area.

Sampling

For a total of five days the presence and site fidelity of the individuals and their range of motion were monitored. Sampling was done at ebb tide ± 90 minutes, both during the day and night. Initially each zone was photographed (e. g. Fig. 1). To calculate the reference size of each zone the distance between the two individuals that were furthest apart was measured at the beginning of the trial. A reference size was calculated with

with these distances.
The individuals were counted at the site each time sampling was done. The site fidelity was monitored by comparing the pictures taken during the day to the reference. Individuals, that were not at their home scar at least once were counted. The distance between the two individuals that were the furthest apart was measured every time sampling was done at night. These measurements were used to calculate the size of this area at the time of sampling. In further calculations, the daily measured sizes were compared to the reference size single handedly.

Calculations
The ratio of animals that was found back at the homescar during daytime and the animals that were missing or at another spot throughout the trial was calculated in percent. To determine differences of the ranges of motion between the different zones, we compared the sizes of the zones to the respective reference. To approach the daily range of motion, we calculated the size of the zones as circular shaped surfaces. The measured distances were used as the diameter of the area. The range of motion was then calculated as the factor between the sizes of the zones at night compared to the reference as: Range of motion = SIZE (Sample X) / SIZE (Sample 1). The average for each zone was calculated. Furthermore, we used a double-sided T-Test using R Studio (Version 1.1.419 – © 2009-2018 RStudio, Inc.) to compare the zones with each other. Comparisons were made between the zones along the transects at both sites (e.g. zones 1, 2 & 3) as well as between the corresponding zones of both collection sites (e.g. zones 1 & 4, 2 & 5 etc.).

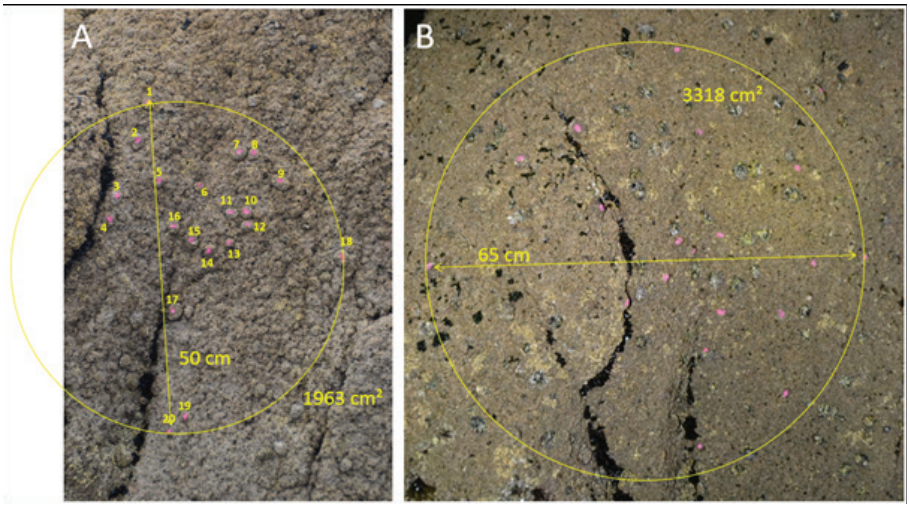

Fig. 1: Zone 2 (Concarneau); A) shows *Patella* spec. during the day (first sampling). B) shows the same specimens during the night (second sampling). To approach the daily range of motion, we calculated the area of the zones as circular shaped surfaces. To calculate the area of each zone the distance between the two individuals that were the furthest apart was measured.

Results

Patella shows a high rate of home fidelity
To determine the home fidelity of *Patella* spec. we calculated the ratio of animals that returned to their home scar every day versus the animals that had beend found at a different spot or missing at least once. 94.2% of the animals were found at the respective home scar during each day. 5.8% of the specimens were not found at the home scar at least once (7 out of 120). One individual could not be found (Zone 2, 7th sampling) and did not reappear. The same individual had been found at a surprisingly large distance from the respective zone (6th sampling).

Limpets closest to the LWL show the highest movement radius
To investigate the range of motion of *Patella* spec., we calculated the sizes of the zones and compared them to each other. Fig. 2.2.1 shows the range of motion of the animals in the zones 1, 2 and 3 (Concarneau). The animals in zone 1 present a significantly larger range of motion than the animals in the other two zones (2.08 ± 0.39). The animals in zone 2 show a higher range of motion than the ones in zone 3 (1.84 ± 0.35 and 1.44 ± 0.30 respectively), although the differences are not significant (Fig. 2.2.1). Fig. 2.2 shows the zones 4, 5 and 6 (Le Cabellou). The animals in zone 4 present the highest range of motion (5.22 ± 1.09), the animals in zone 5 the lowest (1.74 ± 0.30). The animals in zone 6 had a range of motion of 2.20 ± 0.16. The differences are significant in all three zones (Fig. 2.2).

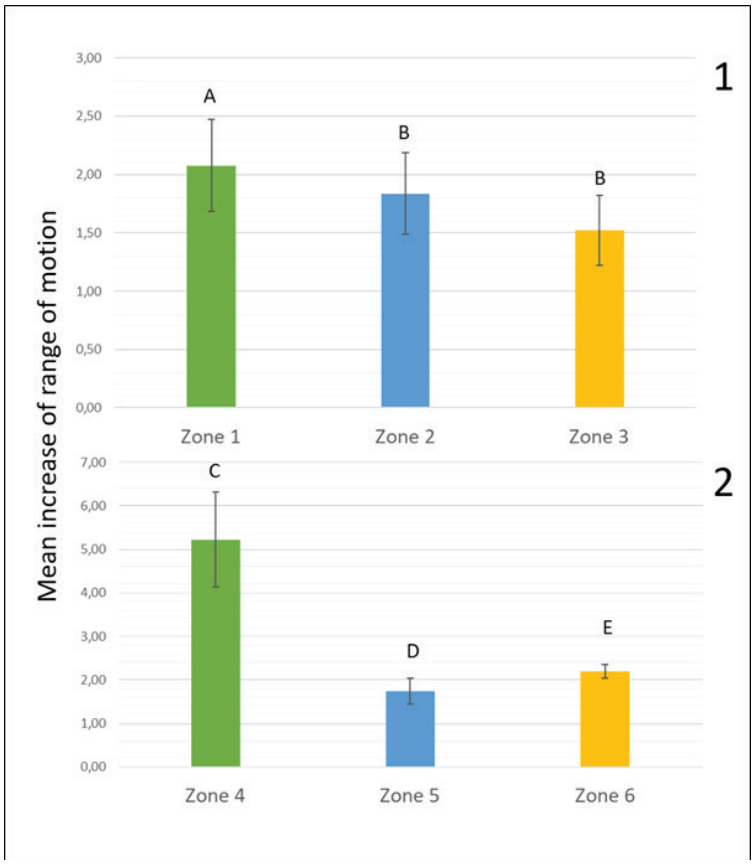

Fig. 2: Mean increase of range of motion of *Patella* spec. in 1) Concarneau and 2) Le Cabellou in different distances from the low water line from close (Zones 1 and 4) to far (zone 3 and 6). Significant differences are marked by different letters.

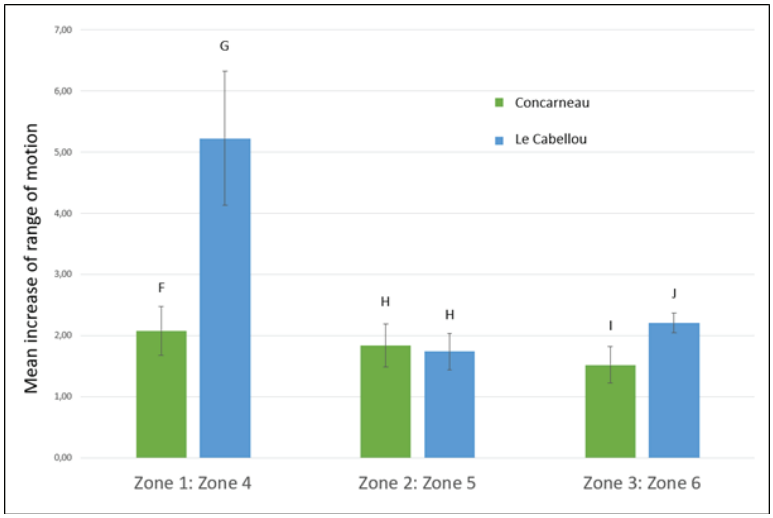

Fig. 3: Comparison of the mean increase of range of motion of *Patella* spec. in Concarneau (green) and Le Cabellou (blue) in different distances from the low water line from close (Zones 1 and 4) to far (zone 3 and 6). Significant differences are marked by different letters.

The movement radius of the limpets in Le Cabellou is higher than in Concarneau

To investigate possible differences in range of motion between Le Cabellou and Concarneau, We compared the corresponding zones of both sites (Fig. 3). We found a significant difference in the lower zones (1 and 4), where the range of motion is higher in the limpets at Le Cabellou than in Concarneau (5.22 ± 1.09 and 1.63 ± 0.39 respectively, Fig. 3). In the upper shore (Zones 3 and 6) the tendency was quite similar and the limpets at Le Cabellou showed to have a larger range of motion than Concarneau as well (2.20 ± 0.16 and 1.52 ± 0.30 respectively, Fig. 3). In the middle shore (Zones 2 and 5) no significant difference could be found between Le Cabellou and Concarneau (1.74 ± 0.30 and 1.84 ± 0.35 respectively, Fig. 3).

Overall a tendency of a higher range of motion close to the LWL was observed (Fig. 3). Additionally, we pooled the zones 1 to 3 and 4 to 6 and compared the average range of motions of both areas in general. The overall average range of motion for Le Cabellou showed to be significantly higher than in Concarneau (3.06 ± 1.72 and 1.81 ± 0.40 respectively). This can be due to numerous reasons that we did not monitor with sufficient detail, like differences in the terrain or differences in direct sunlight radiation. Further experiment to investigate the influence of site properties should be done in the future.

Discussion

Home fidelity in *Patella* spec. in the field has already been observed in 1903 (Davis und Fleure 1903) as well as under laboratory conditions (Funke 1968; Edelstam und Palmer 1950). This behaviour is a powerful mechanism to lower the risk of predation as they are able to adapt their shell perfectly to their subsoil over time by actively rasping the substrate off their home scars with their goethite teeth (Funke 1968; Lowenstam 1962) minimizing the risk of predation , once the shell perfectly matches the subsoil. In the tidal zone of Concarneau and Le Cabellou we determined a high percentage of home fidelity of 94.2% (113 out of 120). Only a few (seven out of 120) specimens did not return to their home scars regularly during the experimental period although they were all found in the surrounding area except one specimen. It cannot be ruled out that sites we determined as home scars are actually the home scars as they can leave or change their home scars over several weeks or months (Funke 1968). One of the specimens got lost after 2 nights after it was seen unusually far away from its home scar the previous night. We can only speculate about a reason for that but there is a possibility of predation.

Observing the range of motion in relation to the distance to the low water line showed variation between the zones. Specimens closer to the LWL present a significantly larger range of motion than the ones further away both in Concarneau and Le Cabellou (Fig. 2). Those specimens are exposed to water for a longer period of time and thus have more time to return to their home scars with lower risk of drying out. The further away the limpets are from the LWL the more irrelevant the differences between the zones become. High on the shore, where space becomes more and more limiting, competition over the best spots enhances territorial behaviour of *Patella* (Branch 1975). With less appropriate places the limpets have been observed to mark their territory and thus cut off their competitors' way with their individually smelling mucus trace (Funke 1968) resulting in lower range of motion. The differences of air exposure become less relevant as the territorial pressure gives priority to other factors like the characteristics of the area. Here, features like gradient angle and thus shadiness and moistness are the limiting factors of the range of motion. Therefore in Concarneau the middle and the upper zone show no significant differences whereas in Le Cabellou in the zone furthest from the LWL the limpets move more than in the middle zone.

Moreover, there were significant differences between the zones when comparing the two sites with each other. The limpets in Le Cabellou presented a significantly larger movement radius than the ones in Concarneau (Fig. 3). The site properties were very different between Le Cabellou and Concarneau. The limpets in the middle and upper zones in Concarneau were sitting on a significantly steeper angle than the limpets in the respective zones in Le Cabellou. Different properties that might differ in the two beaches could influence the activity of *Patella* like food supply, the angle of inclination, the presence of Balanidae or the species composition (Davis und Fleure 1903). Observing and quantifying these differences could be an interesting approach for future studies that might deal with the surface quality of the two areas.

It is worth mentioning that interspecific variation has not been considered in this study. Detaching the limpets is necessary to identify them to species level. Therefore, we deliberately did not do this to guarantee that all individuals were not harmed in the process of the experiment. Furthermore, it has been shown to be difficult to detach the animals from the ground without damaging them (Davis und Fleure 1903), which is not in our interest. For the same reason, we refrained from individually marking the specimens and their location, as their sensitive coattacles, which are responsible for their orientation, could be disturbed by the distinctive colour odour (Funke 1968). It is shown that the behavior of *Patella* can be studied adequately without invasive measures.

Outlook

Our results suggest, that the observation of more zones in one area might improve the results. Also, sectioning the upper shore of an area into more than two zones might provide crucial information about the importance of air exposure time and the influence of other factors in relation to it. Our results don't provide enough information to make precise assumption about these specific parameters. Additionally, zones with comparable properties may increase the precision of the results, as the site properties appear to be crucial to the behavior of the limpets. Variations of the angle, the moisture and shadiness may influence the range of motion and therefore should be further explored. Additionally, more detailed information about the indivi-

dual range of motion could be useful for more specific conclusions. Better results might be obtained by placing cameras photographing the zones in regular intervals. These could be either submergible to leave them installed during the experiment or markings could help to place them on the same position every time sampling is done. Individual locomotion patterns could be analyzed and reveal potential correlations of range of motion and size or population density.

References

Branch, G. M. (1975): Mechanisms Reducing Intraspecific Competition in *Patella* spp.: Migration, Differentiation and Territorial Behaviour. The Journal of Animal Ecology 44 (2), S. 575.

Davis, James Richard Ainsworth; Fleure, H. J. (1903): *Patella*, the common limpet / by J.R. Ainsworth Davis and H.J. Fleure. London: Williams & Norgate.

Edelstam, Carl; Palmer, Carina (1950): Homing Behaviour in Gastropodes. Oikos 2 (2), S. 259.

Fingerman, Milton (1957): Lunar Rhythmicity in Marine Organisms. The American Naturalist 91 (858), S. 167–178.

Funke, Werner (1968): Heimfindevermögen und Ortstreue bei *Patella* L. (Gastropoda, Prosobranchia). Oecologia 2 (1), S. 19–142.

Kohn, Alan J. (1961): Chemoreception in Gastropod Molluscs. American Zoologist 1 (2), S. 291–308.

Lowenstam, H. A. (1962): Goethite in Radular Teeth of Recent Marine Gastropods. Science (New York, N.Y.) 137 (3526), S. 279–280.

Maier, H. und Mielke, M. (2016): Die Schalenmorphologie von *Patella* spp. an der bretonischen Atlantikküste ist standortabhängig. Proceedings in Marine Biology (11).

Villee, C. A.; Groody, T. C. (1940): The Behavior of Limpets with Reference to Their Homing Instinct. American Midland Naturalist 24 (1), S. 190.